Ecological Building: a sustainable approach to design, construction, and operation of buildings

ECOLOGICAL BUILDING:
a sustainable approach to design, construction and operation of buildings

Prof. Arch. Mario GROSSO,
Associate Professor of Architectural Technology
Environmental Consultant
mario.grosso@polito.it

High Level Forum on Clean Energy Technologies
Session 4: Green Society Concept and Practice
SIEEB, Tsinghua, Beijing, March 29, 2011
ECOLOGICAL BUILDING - Prof. arch. Mario Grosso

Ecological building is a multi-faceted process aiming at mitigating the negative environmental impacts of building constructions as well as rationalising the use of resources and enhancing health and comfort for users.

The sustainable approach to ecological building can be described through the following aspects:

1. **Climate change**
2. **Strategies**
3. **Standards**
4. **Evaluation tools: life cycle cost**
5. **Technolgies**
   - 5.1. Water saving
   - 5.2. Indoor air quality and materials
   - 5.3. Construction systems
   - 5.4. Energy and indoor microclimate control
   - 5.5. Technological and architectural integration

High Level Forum on Clean Energy Technologies
Session 4: Green Society Concept and Practice
SIEEB, Tsinghua, Beijing, March 29, 2011
ECOLOGICAL BUILDING - Prof. arch. Mario Grosso

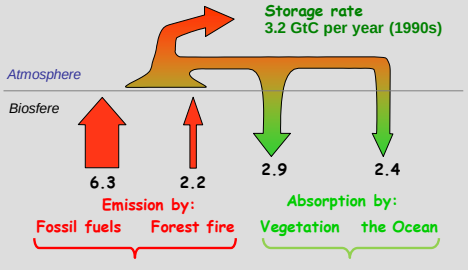
1
CLIMATE CHANGE

High Level Forum on Clean Energy Technologies
Session 4: Green Society Concept and Practice
SIEEB, Tsinghua, Beijing, March 29, 2011
ECOLOGICAL BUILDING - Prof. arch. Mario Grosso

Global warming due to greenhouse gasses emission and concentration in the atmosphere

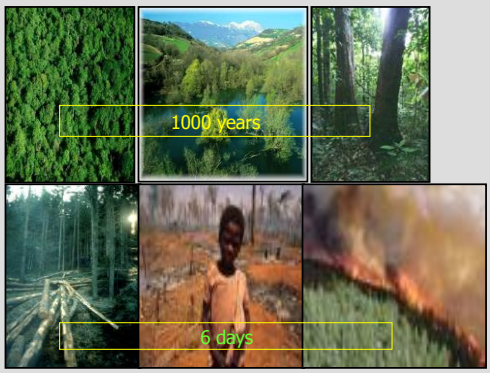
High Level Forum on Clean Energy Technologies
Session 4: Green Society Concept and Practice
SIEEB, Tsinghua, Beijing, March 29, 2011
ECOLOGICAL BUILDING - Prof. arch. Mario Grosso

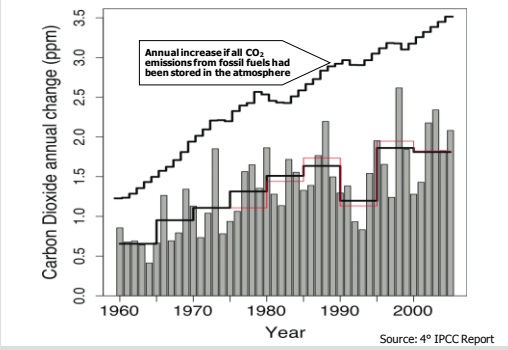
Carbon global balance: "Slow in – Fast out"



Quick processes ($1 – 10^2$ days) Slow processes ($10^3 – 10^4$ days)

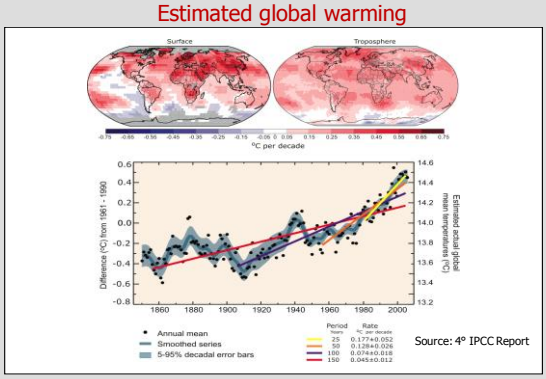
High Level Forum on Clean Energy Technologies
Session 4: Green Society Concept and Practice
SIEEB, Tsinghua, Beijing, March 29, 2011
ECOLOGICAL BUILDING - Prof. arch. Mario Grosso





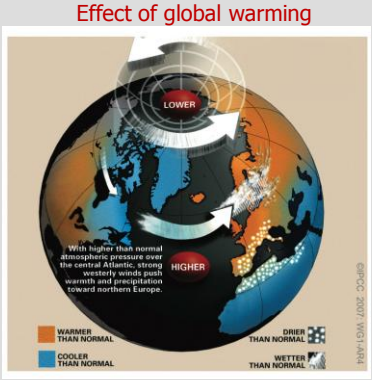
Source: 4° IPCC Report

Estimated global warming



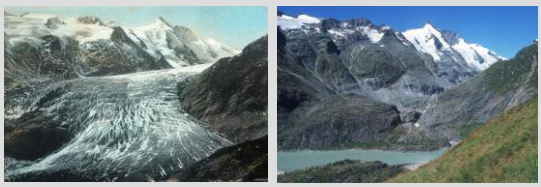
Source: 4° IPCC Report

Effect of global warming



Effect of global warming

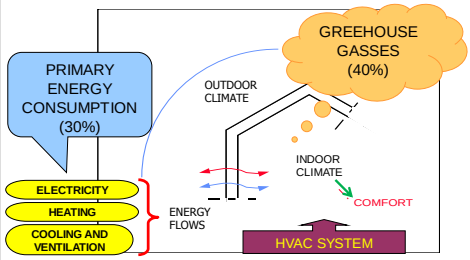
Il ghiacciaio del Grosglockner (3.798 m *s.l.m.*), Austria



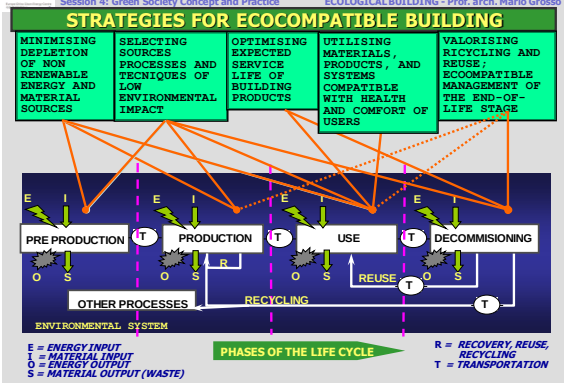
Anno 1900 Anno 2000

Courtesy of Norbert Lantschner

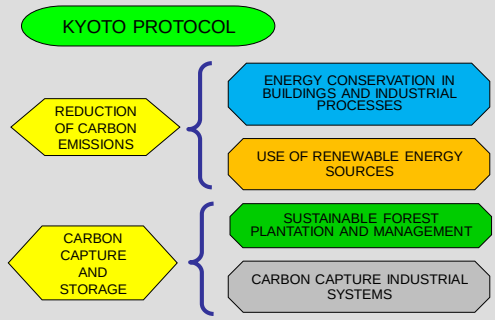
Contribution of the buiding sector to Carbon emissions



2
STRATEGIES



Strategies for reducing global warming potential



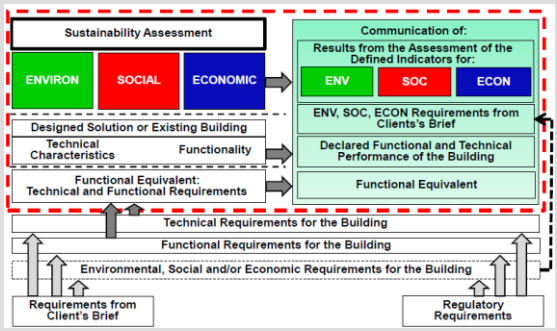
3

STANDARDS

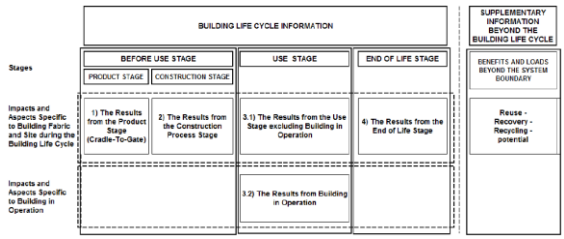
Sustainability of Construction Works – CEN/TC350

- **European horizontal standards for the sustainability assessment of buildings → One system in Europe**
- **Sustainability assessment with the performance based approach in terms of:**
  - **Environmental performance (Mandate M/350)**
  - **Social performance**
  - **Economic performance**
- **Life cycle approach with the quantifiable indicators**

CEN/TC350 – Concept of Sustainability Assessment



CEN/TC350 – The organisation of th results of the assessment in accordance with the life cycle stages and the information groups



4

EVALUATION TOOLS: LIFE CYCLE COST

Life Cycle Costing: a method to calculate an *economic-environmental efficiency factor* for building design

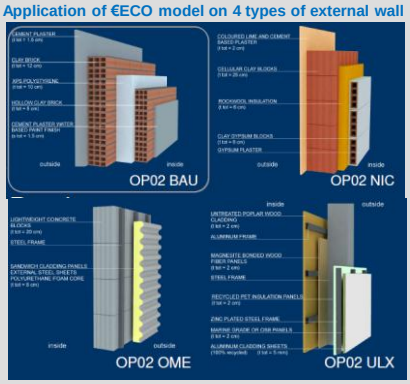
It is a useful tool for guiding the decision process of designers and clients at a preliminary level.
The factor, named **€CO**, integrates the economic aspect into an environmental evaluation model.
It is based on life cycle at the scale of the technical component (building envelope).

$$€CO = (X_{LCC} * \eta_{LCC}) + (X_{GWP} * \eta_{GWP}) + (X_{CED} * \eta_{CED})$$

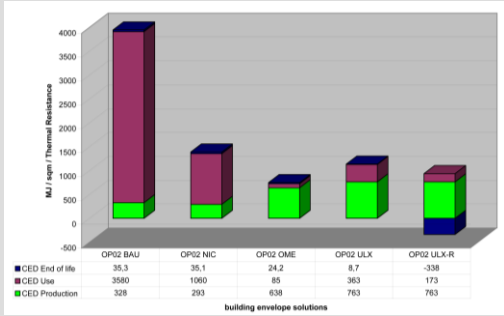
X_{LCC} = Economic Performance
X_{GWP} = Environmental Performance (Global Warming Potential)
X_{CED} = Environmental Performance (Cumulative Energy Demand)

η_{LCC} = Weight of LCC
η_{GWP} = Weight of GWP
η_{CED} = Weight of CED

Application of €ECO model on 4 types of external wall



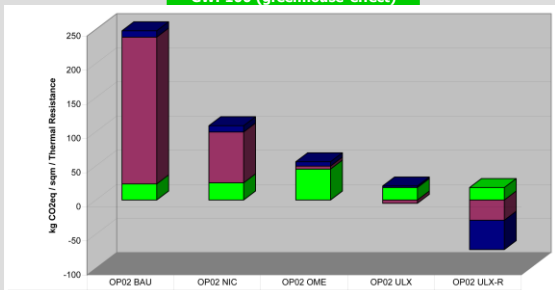
IMPACT ASSESSMENT
CED (Cumulative energy demand)



	OP02 BAU	OP02 NIC	OP02 OME	OP02 ULX	OP02 ULX-R
CED End of life	35,3	35,1	24,2	8,7	-338
CED Use	3580	1060	85	363	173
CED Production	328	293	638	763	763

building envelope solutions

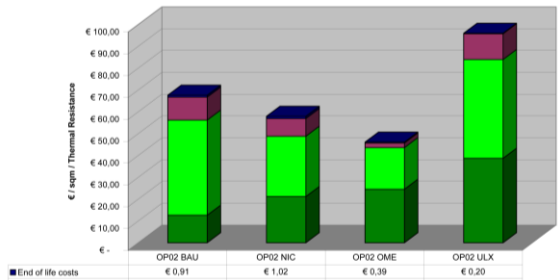
IMPACT ASSESSMENT
GWP100 (greenhouse effect)



	OP02 BAU	OP02 NIC	OP02 OME	OP02 ULX	OP02 ULX-R
GWP End of life	9,31	9,26	6,39	2,3	-43
GWP Use	215	74,4	4,36	-4,81	-29,6
GWP Production	23,6	25,2	45,3	18,3	18,3

building envelope solutions

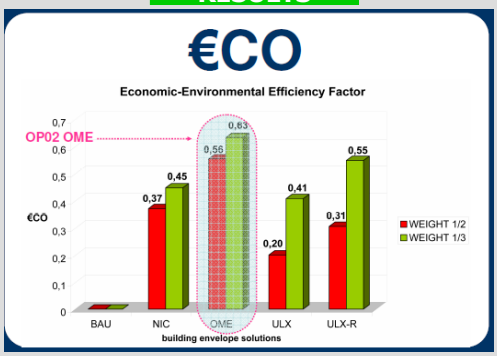
IMPACT ASSESSMENT
LCC (Life Cycle Costs)



	OP02 BAU	OP02 NIC	OP02 OME	OP02 ULX
End of life costs	€ 0,91	€ 1,02	€ 0,39	€ 0,20
Use and Maintenance costs	€ 10,50	€ 8,11	€ 2,12	€ 11,80
Installation costs	€ 43,59	€ 27,64	€ 19,07	€ 45,28
Purchase costs	€ 12,62	€ 21,16	€ 24,52	€ 38,70

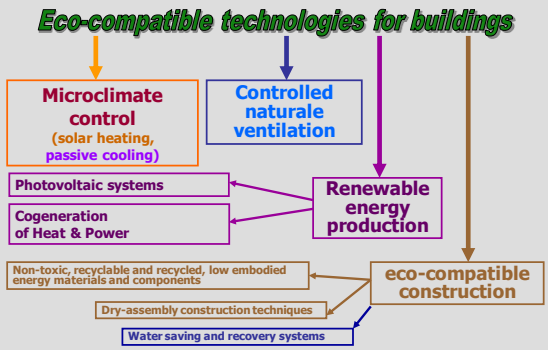
building envelope solutions

RESULTS



5

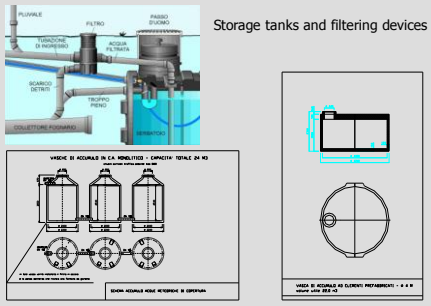
TECHNOLOGIES



5.1

WATER SAVING

Storm water storage for non-potable reuse (irrigation, washing, ...)



Storage tanks and filtering devices

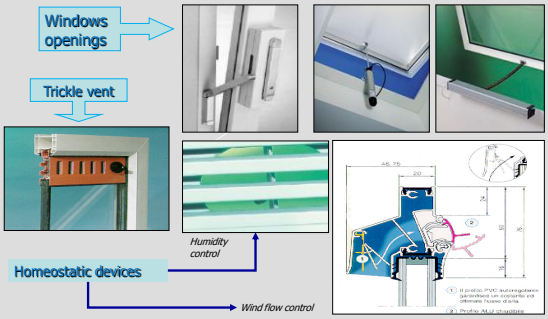
5.2

INDOOR AIR QUALITY AND MATERIALS

Natural ventilation through automatically controlled openings

Windows openings

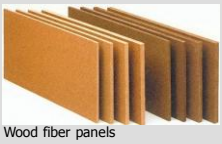
Trickle vent



High Level Forum on Clean Energy Technologies
Session 4: Green Society Concept and Practice
SIEEB, Tsinghua, Beijing, March 29, 2011
ECOLOGICAL BUILDING - Prof. arch. Mario Grosso

Bbuilding products of natural components

Cellulose fiber panels



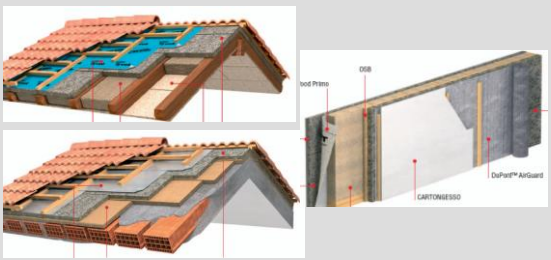
Wood fiber panels

Wood brick-like elements

Cooked clay panels

High Level Forum on Clean Energy Technologies
Session 4: Green Society Concept and Practice
SIEEB, Tsinghua, Beijing, March 29, 2011
ECOLOGICAL BUILDING - Prof. arch. Mario Grosso

Wood-cement insulation panels



High Level Forum on Clean Energy Technologies
Session 4: Green Society Concept and Practice
SIEEB, Tsinghua, Beijing, March 29, 2011
ECOLOGICAL BUILDING - Prof. arch. Mario Grosso

Recycled materials

http://www.matrec.it/

High Level Forum on Clean Energy Technologies
Session 4: Green Society Concept and Practice
SIEEB, Tsinghua, Beijing, March 29, 2011
ECOLOGICAL BUILDING - Prof. arch. Mario Grosso

Embodied energy in materials

1600 °C process temperature
to produce cement

900° process temperature
to produce bicks

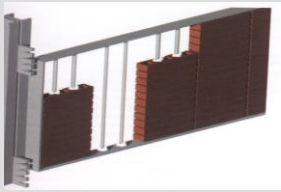
Solar energy to grow wood
Electricity do process timber in mills

High Level Forum on Clean Energy Technologies
Session 4: Green Society Concept and Practice
SIEEB, Tsinghua, Beijing, March 29, 2011
ECOLOGICAL BUILDING - Prof. arch. Mario Grosso

5.3

CONSTRUCTION SYSTEMS

DRY ASSEMBLY CONSTRUCTION SYSTEM



International Exibition "Colombiadi", Genoa (1985-92) – arch. Renzo Piano

Brick panel

DRY ASSEMBLY CONSTRUCTION SYSTEM

BUILDING "C1", POTSDAMER PLATZ, BERLINO
Arch. R. PIANO e Arch. KOHLBECKER

Brick panels

Detail

DRY ASSEMBLY CONSTRUCTION SYSTEM

RESIDENTIAL BUILDING, SAINT MARTIN D'HERES, GRENOBLE, 1996 – Archs. DUBOSC E LANDOWSKY

Modular metal cladding with acoustic insulation.

View from street

Wood cladding with diagonal layout

View from courtyeard

DRY ASSEMBLY CONSTRUCTION SYSTEM

EMSHER PARK, ESSEN, Archs. JOURDA e PEROUDIN

Roof panels of double glazing with interplaced FV cells

Local wood pillars, with bolted steel joints to the roof

Modular pre-fabbricated wall

DRY ASSEMBLY CONSTRUCTION SYSTEM

Office building, Environment Park, Turin
Archs. Dotta e Fassi

Energy-environmental Consultant: Mario Grosso

5.4

ENERGY AND MICROCLIMATE CONTROL

SPACE HEATING

Thermal control

- **Solar storage**
- **Thermal inertia**
- **Thermal insulation**

Solar heating

passive	active
Sun space	Water solar collectors
Trombe-Michel wall	Air solar collectors
Solar chimney wall	

High Level Forum on Clean Energy Technologies
Session 4: Green Society Concept and Practice
SIEEB, Tsinghua, Beijing, March 29, 2011
ECOLOGICAL BUILDING - Prof. arch. Mario Grosso

SPACE COOLING

Thermal control

- **Solar control**
- **Thermal inertia**
- **Internal gains**

Natural cooling (thermal sinks)

convection	conduction-radiant exchange
microclimate (ventilation through outdoor air)	geothermal (hypogeum buildings, water-to-earth exchange)
geothermal (air-to-earth exchange through horizontal buried pipes)	radiant (direct)
evaporative cooling (through sprayed water)	
radiant cooling (through air ducts)	

High Level Forum on Clean Energy Technologies
Session 4: Green Society Concept and Practice
SIEEB, Tsinghua, Beijing, March 29, 2011
ECOLOGICAL BUILDING - Prof. arch. Mario Grosso

ENERGY PRODUCTION FOR SERVICES

ELECTRICITY

- *PV systems to grid*
- *PV stand-alone systems*
- *Other RES system (wind, micro-hydro)*
- *H&P Co-generation systems*

WATER HEATING

- *Solar systems*
- *District heating*

High Level Forum on Clean Energy Technologies
Session 4: Green Society Concept and Practice
SIEEB, Tsinghua, Beijing, March 29, 2011
ECOLOGICAL BUILDING - Prof. arch. Mario Grosso

Thermal control: green roofs

High Level Forum on Clean Energy Technologies
Session 4: Green Society Concept and Practice
SIEEB, Tsinghua, Beijing, March 29, 2011
ECOLOGICAL BUILDING - Prof. arch. Mario Grosso

Passive and active Solar space heating

EU-funded residential buildings programme, Piedmont, Italy, 1983-86

Air solar collector on walls

Air solar collector on roof and sun spaces on the south wall

High Level Forum on Clean Energy Technologies
Session 4: Green Society Concept and Practice
SIEEB, Tsinghua, Beijing, March 29, 2011
ECOLOGICAL BUILDING - Prof. arch. Mario Grosso

Passive and active Solar space heating

EU-funded residential buildings programme, Piedmont, Italy, 1983-86

Air solar collector on roof

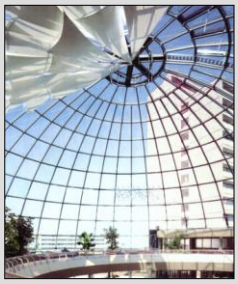
Passive and active Solar space heating

Water solar collector on roof and sun spaces on the south wall

EU-funded residential buildings programme, Piedmont, Italy, 1983-86

Solar control

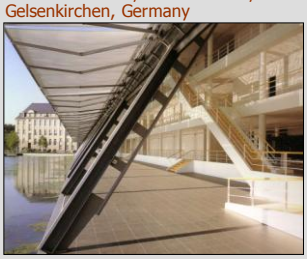
Siville, Spain: mobile canvasses on a street.



Arch. Reidemeister und Glassel, Dome of Bad Neutadt Hospital, Berlin

Solar control

Kiessel + Partner, Scientific Park, Gelsenkirchen, Germany

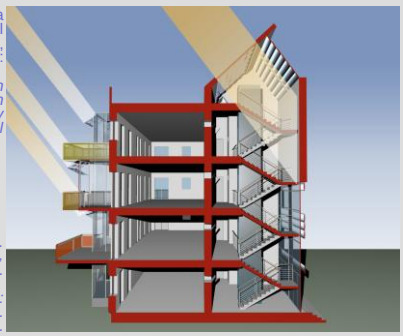


Renzo Piano Building Workshop, Refurbishment of Lingotto Building, Turin, Italy

Solar-chimney-driven ventilation

Design of a residential building, Rome, Italy:

3-D representation of solar irradiation on the chimney wall



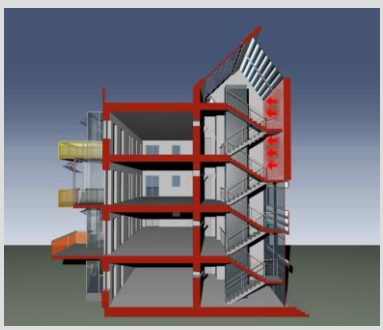
Designer: Arch. M. Irene Cardillo, Roma.

Consultant : Prof. arch. M. Grosso.

Solar-chimney-driven ventilation

Design of a residential building, Rome, Italy:

3-D representation of night re-irradiation from the solar chimney wall.



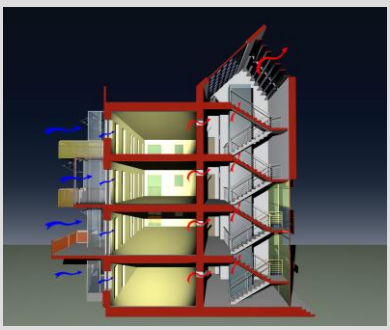
Designer : Arch. M. Irene Cardillo, Roma.

Consultant : Prof. arch. M. Grosso.

Solar-chimney-driven ventilation

Design of a residential building, Rome, Italy:

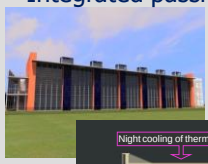
3-D representation of airflow during a summer night



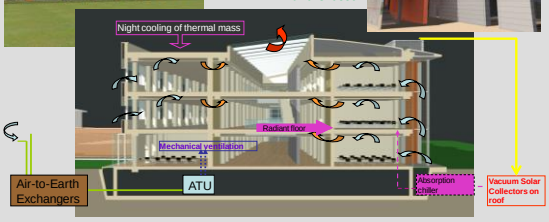
Designer : Arch. M. Irene Cardillo,

Consultant : Prof. arch. M. Grosso

Integrated passive and hybrid cooling systems

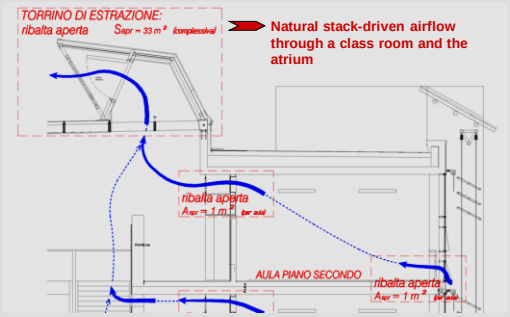


High School Building, Imola, Italy
Arch. Dal Fiume e Gaddoni
Energy-environmental Consultant : Mario Grosso



High School Building, Imola, Italy

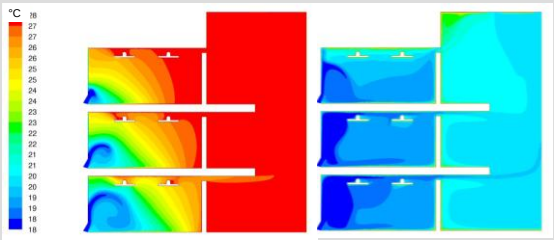
Night cooling of thermal mass



High School Building, Imola, Italy

Night cooling of thermal mass

2D CFD Simulation: temperature zones for a gradient of 10 °C between inside and outside



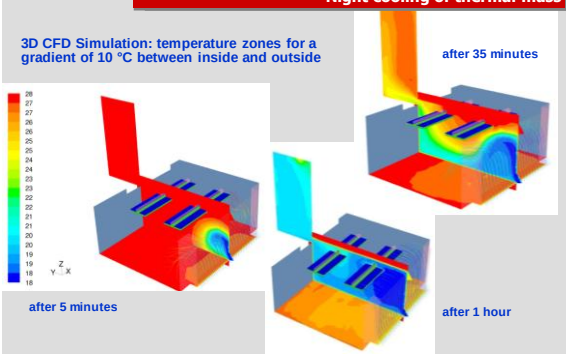
after 1 minute

after 10 minutes

High School Building, Imola, Italy

Night cooling of thermal mass

3D CFD Simulation: temperature zones for a gradient of 10 °C between inside and outside



after 35 minutes

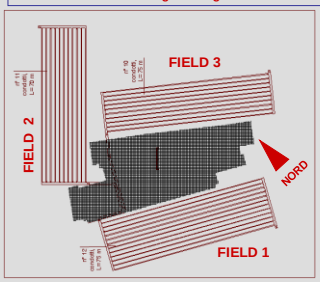
after 5 minutes

after 1 hour

High School Building, Imola, Italy

Ait-to-earth heat exchangers

Air-to-earth heat exchange through horizontal buried pipes



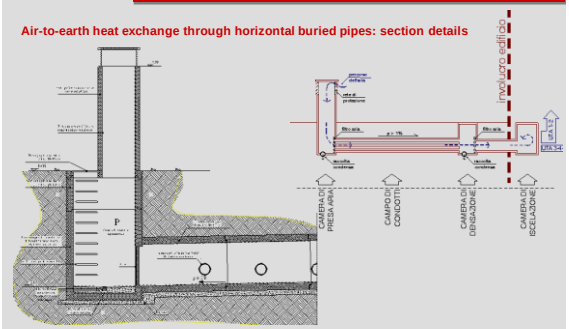
Characteristics:

- 40000 m³ treated air
- Pipes average depth: 2.5 m
- Pipe material: Polyethilene
- Small pipe diameter = 0.25 m
- Large pipe diameter = 0.80 m
- Total pipe length: about 2 Km
- Filter of air and water drainage

High School Building, Imola, Italy

Ait-to-earth heat exchangers

Air-to-earth heat exchange through horizontal buried pipes: section details

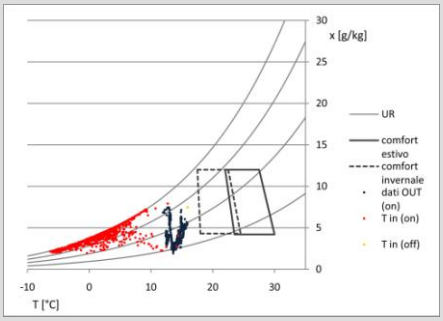


High School Building, Imola, Italy
Ait-to-earth heat exchangers

Pipes installation

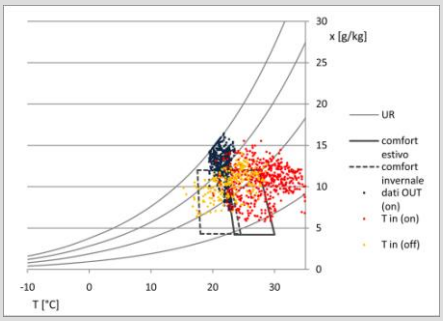
High School Building, Imola, Italy
Ait-to-earth heat exchangers

Elaboration of the first moitoring data
(December, 2010)



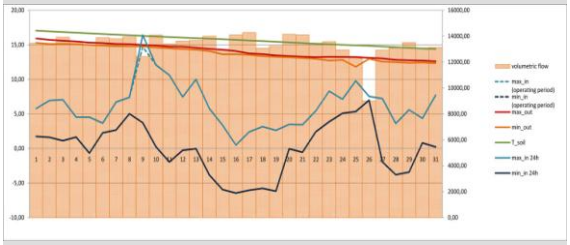
High School Building, Imola, Italy
Ait-to-earth heat exchangers

Elaboration of the first moitoring data
(July, 2010)



High School Building, Imola, Italy
Ait-to-earth heat exchangers

Elaboration of the first moitoring data
(December, 2010)



High School Building, Imola, Italy
Ait-to-earth heat exchangers

Elaboration of the first moitoring data
(July, 2010)

5.5

TECHNOLOGICAL AND ARCHITECTURAL INTEGRATION

INTEGRATION OF SOLAR COLLECTOR ON ROOF AND WOOD CLADDING OF WALL

Nursery buiding Nichelino (Turin, Italy), Arch. Valerio Sticca, and Giancarlo Pavoni

Consultant : Mario Grosso

High Level Forum on Clean Energy Technologies
Session 4: Green Society Concept and Practice
SIEEB, Tsinghua, Beijing, March 29, 2011
ECOLOGICAL BUILDING - Prof. arch. Mario Grosso

INTEGRATION OF A SEMI-HYPOGEUM BUILDING IN A LANDSCAPED CONTEXT

Arts Park, Turin, Italy
Arch. Alessandro Fassi